TESTING THE BEARING POWER OF SOILS

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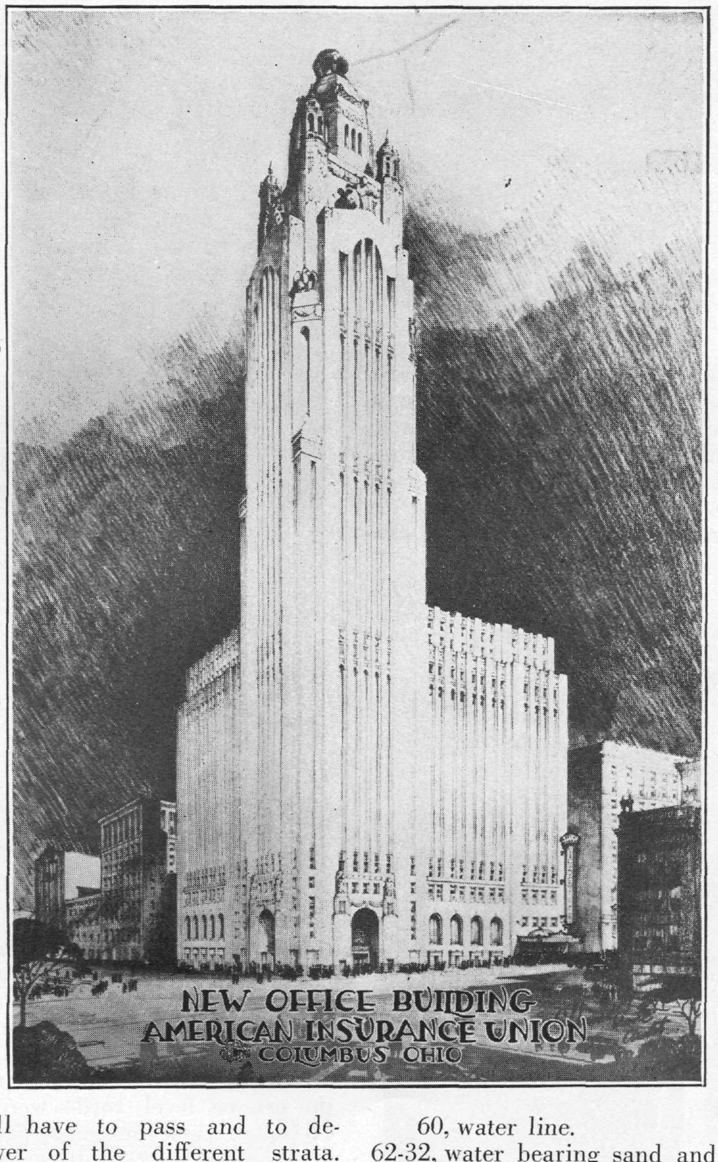
THE foundation is that part of a structure the function of which is to secure adequate support on the earth. In order to find a stratum which has sufficient bearing capacity to sustain the loads without undue settlement, it is usually necessary to excavate to some depth below the surface. The greater the bearing power of the soil, the smaller is the area over which the foundation must be spread. In the design of the foundations for a structure, therefore, there are three problems involved: to find the bearing capacity of the soil, to determine upon the method of spreading to secure the required bearing area and to determine the method of excavating to the stratum on which it is desired to rest the foundation. It is the first of these problems with which this article will deal, although it will be necessary to touch upon the other two to some extent.



Before the design for the foundations of any structure is attempted, an investigation of the underlying soil conditions must be made. The preliminary investigations may be made in a number of ways. The simpler method are: driving rods down to test the resistance of the soil, making borings with ordinary augurs 2 or 2½ inches in diameter, or digging test pits. These methods are limited to shallow depths and the results are unreliable, excepting with the test pits.

Where the depth of a suitable stratum is great or the magnitude of the structure justifies the expense, test wells should be sunk to investigate the character of the material through which the foundations will have to pass and to determine the bearing power of the different strata. These test wells are usually sunk by driving a well casing and bailing out the material. Samples are examined at various depths and a judgment formed as to quality of the starta. When material of suffiicent density is encountered, core borings should be made so that the character of the material can be better known and its bearing power better estimated.

When the excavations for the footings have been carried to a stratum which is thought suitable for bearing the load, test loads are often applied to determine the settlement under load, the rate of settlement and the bearing power. With open excavations, these tests are usually made by balancing a platform on a small bearing area of from 2 to 4 square feet and loading it by means of sand bags or pig iron. Tests were made in this manner of the soil under the footings of the Ohio Stadium, and of the University Bridge.

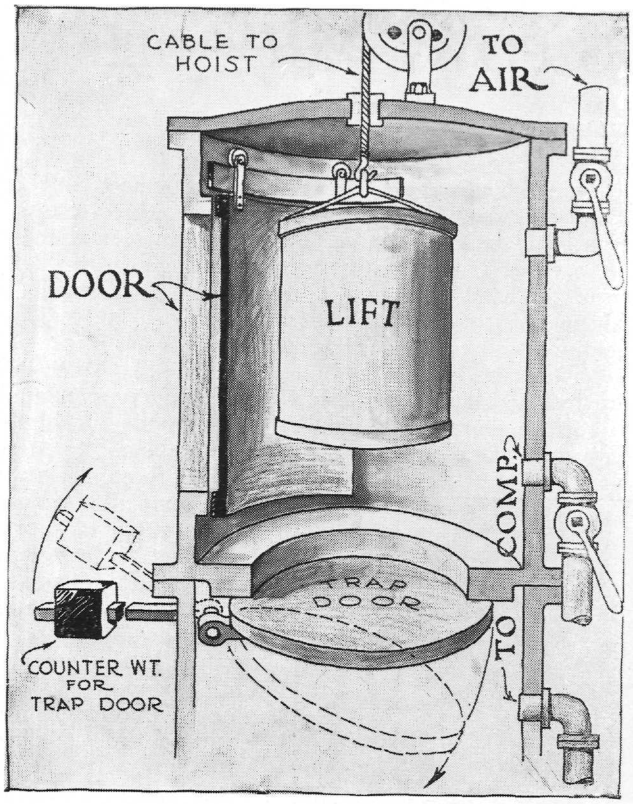
On the site of the Stadium, 24 test wells were sunk previous to making the design, four of these were sunk to rock, a depth of about 57 feet. On the site of the University Bridge four test wells were sunk to rock. Both of these structures were founded on a compact stratum of heavy gravel at a comparatively shallow depth.

The home office building of the American Insurance Union will be, when completed, the tallest building in the world, outside of New York City. Its height is the same as that of the Washington Monument, 555 ft., 5½ in. It is of the tower type of construction with 37 usable floors in the tower. The tower is about 80 ft. square and there are two wings, each 18 stories high, running north and east from the tower, forming an L. In the angle of the L is being built the new Keith Theater, which has a height equal to about seven stories.

Four preliminary test wells were sunk to rock in August, 1924, the record of which is given below.

Elev.	Soil	Depth
102,	Curb level.	
102-82,	sand and gravel	20
82-72,	sand and blue clay	10
72-62,	clay, sand and gravel	10
60,	water line.	
62-32,	water bearing sand and gravel	30
32-22,	fine sand and gravel	10
22- 2,	blue clay and hard pan	20
2- -8,	blue Niagara limestone	10

The elevation of bed rock as indicated by these borings agrees fairly well with that reported in a well at the Ohio Penitentiary about half a mile northwest, and was somewhat deeper than that reported in the old well at the State House, about 600 yards southeast of the site. A careful record of the material passed through in sinking the caissons checks the record of the borings very



Air Lock Detail. Fig. 1

closely with the exception of the elevation of bedrock.

It was first proposed to use caissons under the main tower and wings and spread footings under the theater, but on account of the danger of unequal settlements between the theater and the main building, it was finally decided to go to rock with all the foundations. The 125 columns of the structure rest on a mat of girders of concrete and steel, supported upon 44 caissons. It was thought that the "blue Niagara limestone" indicated by the borings would be safe for a working pressure of 35 tons per sq. ft., and the dimensions of the caissons were determined from this working unit pressure. Their size varied from 6 ft. 6 in. square to 9 ft. square. No allowance was made for skin friction in the calculations, but the entire load plus the weight of the caisson shaft was figured as being carried on the rock.

The caissons were square prisms of reinforced concrete with a circular shaft 3 feet in diameter down the center. At the bottom the shaft was widened out into a working chamber with sloping roof, about 8 feet high and as large as the outside dimensions of the caisson. The cutting edge was formed of a steel angle running entirely around. This cutting edge is shown in the upper part of the photograph. Fig. 3.

Air Lock. Fig. 2

Test Apparatus. Fig. 3

The first cutting edge was set Dec. 27, 1924, and the forms for the working chamber and the lower section of the caisson built. The forms were removed and actual sinking was begun early in January, 1925. The sinking was done by excavating the material under the working chamber and hoisting it out through the central shaft. When the caisson had sunk until the top was nearly at the ground level, forms were again set up and another 16-foot section poured on top. This process of building and sinking was continued until the water line was reached. Then the caisson was completed to its entire height and an air lock installed on top, as shown in Fig. 1. The purpose of the air lock is to make it possible to maintain a sufficient air pressure in the working chamber to prevent the water flowing in and filling it. Fig. 2 shows a caisson with the airlock on top. Compressed air was furnished by four belt driven compressors, each receiving its power from a 500 horsepower motor.

To facilitate sinking, the sides of the caissons were

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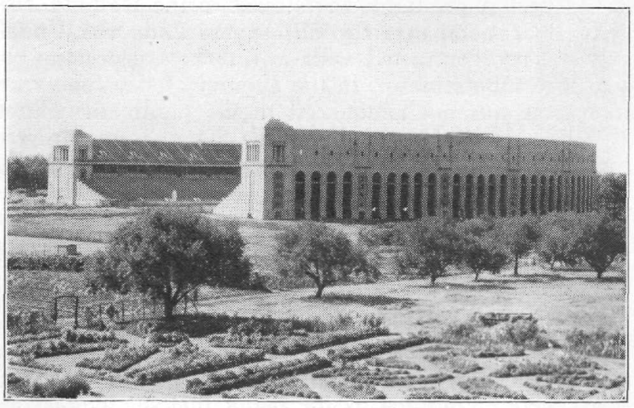

Ohio Stadium

battered 1 inch in 13 feet. As soon as the clay stratum was reached at about elevation 22, the surface friction increased enormously and pig iron had to be piled on the caissons below the air locks to sink them. In some cases as much as 300 tons of pig iron was required in order to force the caisson down into the hole excavated under it.

When the first caisson reached elevation +2, the rock indicated by the borings was not found and the sinking was continued to elevation —10.75. This was as far as it was practical to go with the caisson shaft, but a 4-foot hole was dug 10 feet further, to elevtion —21, searching for limestone, but only the shale-like laminated clay could be found, so it was decided to stop the sinking at —12 and bell out the working chamber below the cutting edge until sufficient area was secured to carry

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the loads at a safe pressure on the laminated clay. The nature of this shale-like material may be judged from the photograph, Fig. 3.

In order to determine the safe bearing power of the soil, pressure tests were made on the soil at the bottom of nine of the caissons, and a representative sample of the material at the bottom of every caisson was cut into cubical form and tested for compressive strength in an ordinary testing machine. The latter tests were made in order to establish a relation between the strength of the material in an unconfined cube and when confined in place in the earth, which could be used in determining the safe loads on the soil at the bottom of the caissons in which no pressure tests were made.

The apparatus used for the pressure tests at the bottom of the caissons is shown in Fig. 3 and consists of a calibrated spring resting on a bearing plate five inches square on the soil. On this spring was placed a 25-ton ball bearing screw jack, which in turn thrust against the under side of the cutting edge of the caisson. The load on the spring was read by means of Ames gauges on the two sides, and by repeated tests in a compression machine it was found to be accurate within about 1%. The settling of the bearing plate into the soil was measured from a fine steel wire stretched from side to side of the excavation in front of the celluloid scale on the mirror shown in Fig 3, which was attached by a bar to the lower leaf of the spring.

The load was applied in increments of about 2,500 pounds until a load of about 25 tons per square foot was reached, when a period of rest was allowed to determine whether settlement continued and the amount of yielding under the load. After this rest period of from 15 to 20 minutes, the load was run up until the material gave way. In two cases the capacity of the apparatus was reached before the material failed. The highest load reached in any test was 84.3 tons per square foot.

As noted above, specimen cubes, about 8″x 8″, from all caissons were tested. The results of these cube tests from the 9 caissons in which pressure tests were run, showed an average strength equal to 31% of that attained on the confined material at the bottom of the caisson, and the bearing power of the soil when confined as it is when the caisson is finally sealed, is no doubt greatly in excess of the pressures sustained under the 5″x 5″ bearing plate in the pressure tests.

The tests were made by the writer with the assistance of Prof. J. R. Shank.